The development of geodetic support means in the Russian Federation

S.N. Karutin, I.V. Gusev,
V.F. Fateev, I.S. Silvestrov,
A.V. Ipatov, I.S. Gayazov,
D.I. Pleshakov, A.N. Zyeva, E.V. Novikov,
I.A. Stolyarov et al.

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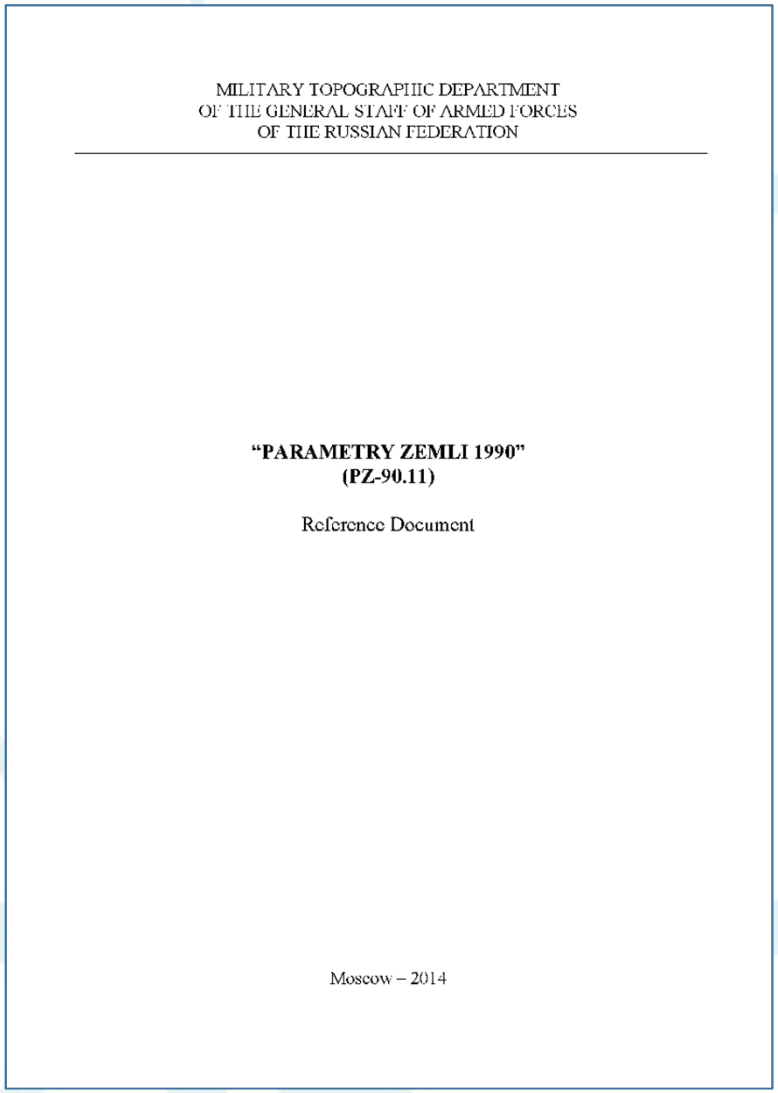
ИАЦ

ICG-10, Boulder, Colorado USA, 1-6 November 2015

I. Technical guidance documents



MILITARY TOPOGRAPHIC DEPARTMENT
OF THE GENERAL STAFF OF ARMED FORCES
OF THE RUSSIAN FEDERATION

"PARAMETRY ZEMLI 1990"
(PZ-90.11)

Reference Document

Moscow – 2014

References: "Parametry Zemli 1990" (PZ-90.11): Reference document. – Moscow: Military Topographic Department of the General Staff of Armed Forces of the Russian Federation, 2014, 52 p.
http://eng.mil.ru/files/PZ-90.11_final-v8.pdf

The following state standards in the field of GNSS were adopted in 2015:

- State Standard GOST R 56411-2015 Global navigation satellite system. ***Methods and technologies of geodetic surveys. General requirements for the co-location sites*** (approved by the order of the Federal Agency on Technical Regulating and Metrology from 28.05.2015 №457-st);
- State Standard GOST R 56408-2015 Global navigation satellite system. ***Satellite geodetic networks. General requirements*** (approved by the order of the Federal Agency on Technical Regulating and Metrology from 28.05.2015 №454-st);
- State Standard GOST R 56410-2015 Global navigation satellite system. ***Methods and technologies of geodetic surveys. General requirements for precise ephemerides centers*** (approved by the order of the Federal Agency on Technical Regulating and Metrology from 28.05.2015 №456-st);
- State Standard GOST R 56409-2015 Global navigation satellite system. ***Geodetic monitoring systems. Test program and methods*** (approved by the order of the Federal Agency on Technical Regulating and Metrology from 28.05.2015 №455-st).

II. Quasar-KVO VLBI complex

Quasar-KVO VLBI complex: new components

13-meter (42,65 feet) radio telescopes (RT-13) in Zelenchukskaya and Badary observatories

Measuring system	Type - Tri-band	S-band	X-band	Ka-band
	Input freq. (GHz)	2,2-2,6	7,0-9,5	28,0-34,0
	Pol type	RCP+LCP	RCP+LCP	RCP+LCP
	T_sys (K)	35*	25*	75*
	SEFD (Jy)	1000*	700*	2200*
		* - early results		

Server system	Type	BRAS
	Input bandwidth (MHz)	512
	Sample clock (MHz)	1024
	number of channels	8
	data rate from channel (Mbs)	2
	data format	VDIF

Antenna	Optics	ring focus
	Az slew rate (°/s)	12
	El slew rate (°/s)	6
	Diameter (m)	13,2
	RMS(mm)	0,2
	Efficiency (%)	>70

Recording complex	Type	DRS / Mark5C
	Recording speed (Gbps)	0,4 (today) / 2 (by the end of 2015)

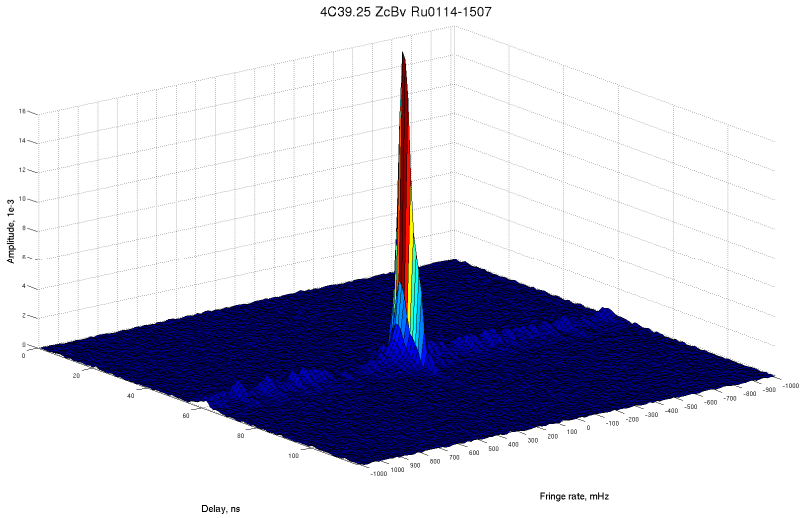
Quasar-KVO VLBI complex: new components

Software correlator (IAA)

- Processing in quasi-real time:
  - Input data from 6 stations, 96 Gbps
  - Calculation of 312 cross-spectrum (4 frequency bands, 2 polarizations, 6 stations), 4096 spectral channels
  - Obtaining 32 levels of phase calibration for each channel of each station
- FX software correlator
- The use of processors (GPUs) NVIDIA Tesla® K20
- Correlator cluster based on hybrid servers (CPU+GPU) consisting of 80 GPUs NVIDIA Tesla® K20 and 80 processors Intel E5-2670 (8-core, 2.6 GHz)

The early correlation results

Date:	16-17 March 2015
Basis:	Badary (RT-13) – Zelenchukskaya (RT-32)
Frequency range:	S & X
Frequency band :	512 MHz
The number of channels :	1 to 4
Data format:	VDIF
Data rate:	2 to 8 Gbps



Quasar-KVO VLBI complex: new components

Water vapor radiometers

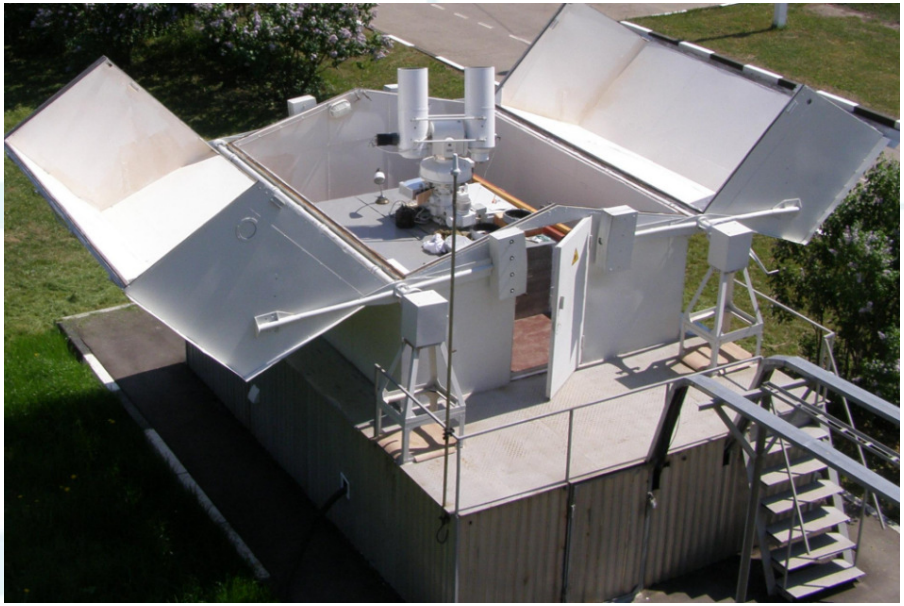
Atmosphere brightness temperature is measured at frequencies 20.7 и 31.4 GHz

$$TWD = \sec\theta\left(0.106\,Q + \frac{1732}{T_m}Q + 1.45W\right)$$

Q, g/cm^2 – water vapor content,
W, kg/m^2 – liquid content

The network of Federal Agency on Technical Regulating and Metrology

№	ID (IGS)	Name	GLO	Co-location	Organization
1	irkj	Irkutsk	+	**SLR IRKL**	VNIIFTRI
2	irkt	Irkutsk			DEOS-DUT/ VNIIFTRI
3	mdvj	Mendeleevo	+	**SLR MDVS Abs. Gravimeter**	VNIIFTRI
4	novm	Novosibirsk	+		VNIIFTRI
5	Planned	Khabarovsk	+		VNIIFTRI
6	Planned	Petr-Kamch	+		VNIIFTRI



III. The modern structure of the state geodetic network

ROSREESTR
The Federal Service for State Registration, Cadastre and Cartography

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The basis of GSK-2011 reference frame is a state satellite geodetic network of the three-tier structure:

- **Fundamental astronomic geodetic network (FAGN)**

  Practical realization of geocentric reference frame for Positioning and Timing in Russia

- **High-precision geodetic network (HPGN)**

  The main functions of HPGN are the expansion of geocentric reference frame on the whole territory of Russia and clarification of the orientation parameters between geocentric and geodetic reference frames

- **Satellite geodetic network of the first class (SGN-1)**

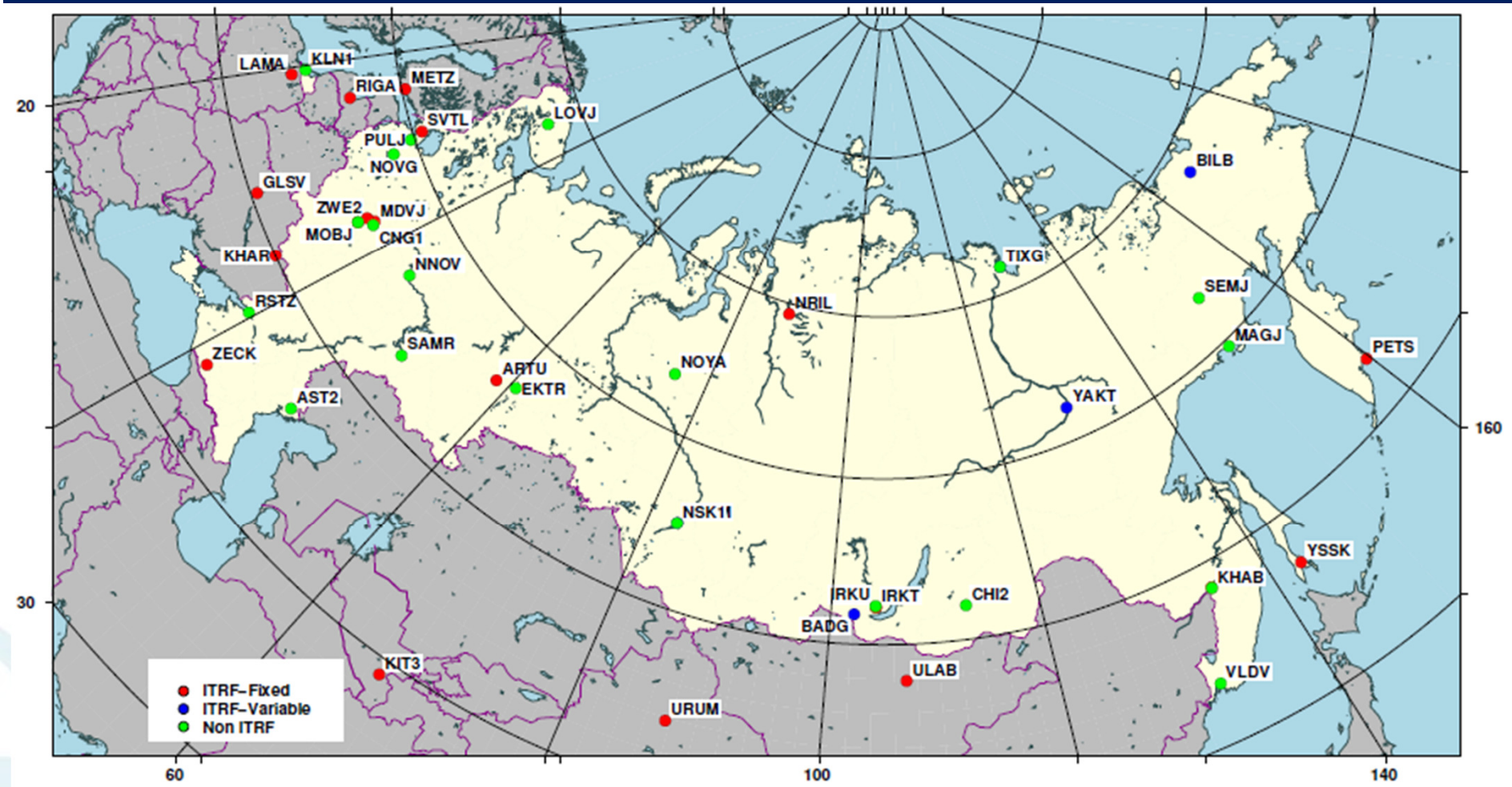
  Provides optimal conditions for realization of accuracy and operational capabilities of the satellite equipment when transferring geodetic support of the Russian territory on the satellite methods of positioning

The development of these networks is primarily performed by the method of relative measurements.

Points involved in fundamental astronomic geodetic network (FAGN) adjustment

№№	Point	Name	ITRF
		Russian territory	
1	ARTU	Arti	X
2	AST2	Astrakhan	
3	BADG	Badary	X
4	BILB	Bilibino	
5	CHI2	Chita	
6	CNG1	Moscow	
7	EKTR	Ekaterinburg	
8	IRKJ	Irkutsk, SSTF	X
9	IRKT	Irkutsk, SSTF	X
10	IRKU	Irkutsk, Rosreestr	
11	KHAB	Khabarovsk, Rosreestr	
12	KHAJ	Khabarovsk, SSTF	X
13	KLN1	Kaliningrad	
14	LOVJ	Lovozero	
15	MAGJ	Magadan	
16	MDVJ	Mendeleevo	X
17	MOBJ	Obninsk, Rosreestr	
18	MOBN	Obninsk, RAS	X
19	NNOV	Nizhny Novgorod	
20	NOVG	Novgorod	
21	NOVM	Novosibirsk, SSTF	X
22	NOYA	Noyabrsk	
23	NRIL	Norilsk	X
24	NSK1	Novosibirk, Rosreestr	
25	PETS	Petropavlovsk-Kamchatsky	X
26	PULJ	Pulkovo	
27	RSTZ	Rostov-on-Don	
28	SAMR	Samara	
29	SEMJ	Sejmchan	
30	SVTL	Svetloe	X
31	TIXG	Tiksi	
32	TIXI	Tiksi, RAS	X
33	TIXJ	Tiksi	
34	VLDV	Vladivostok	
35	YAKT	Yakutsk	
36	YSSK	Yuzhno-Sakhalinsk	X
37	ZECK	Zelenchukskaya	X
38	ZWE2	Zvenigorod	X
		Foreign territory	
39	GLSV	Goloseevo (Kiev), Ukraine	X
40	KHAR	Kharkiv, Ukraine	X
41	KIT3	Kitab, Uzbekistan	X
42	LAMA	Lamkowko, Poland	X
43	METZ	Metsahovi, Finland	X
44	RIGA	Riga, Latvia	X
45	ULAB	Ulan Bator, Mongolia	X
46	URUM	Urumqi, China	X

Points involved in fundamental astronomic geodetic network (FAGN) adjustment



ITRF2008 and GSK-2011 (FAGN) comparison shows that coordinate differences are less than 1 cm. So the reference frame GSK-2011 can be consider as ITRF realization at the epoch 1 January 2011 on the Russian territory.

	RMS of FAGN coordinates after adjustment (cm)
horizontal	0.1 – 1.0
vertical	0.2-1.5

Cartogram of planned FAGN points locations by 2020

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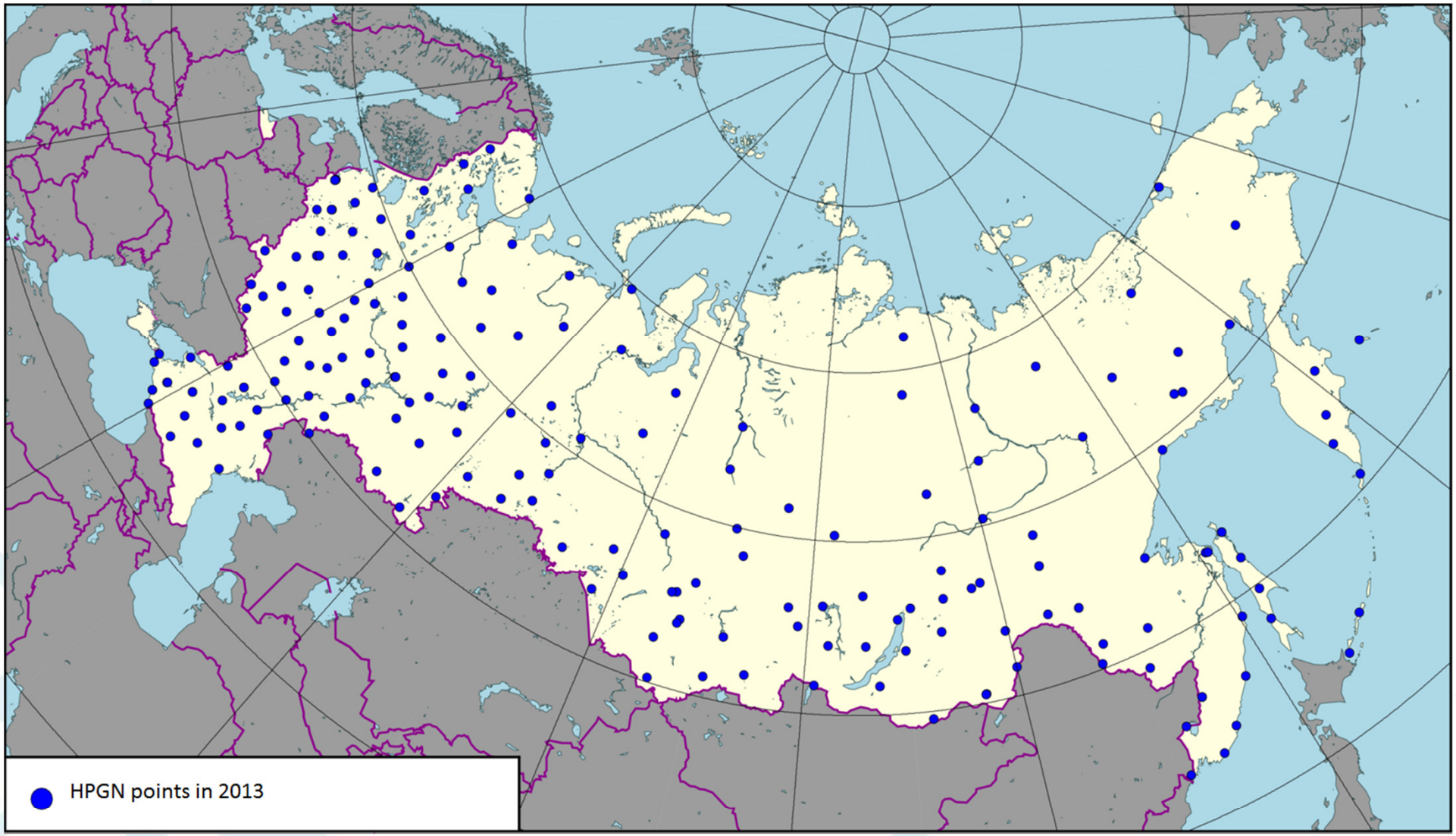
Planned target indicators of the network by 2020:
number of FAGN points – 80;
positioning accuracy – 0.5 cm (horizontal), 1-2 cm (vertical);
relative position of the network points accuracy – 0.5 cm;
normative density – 5 points per 1 million square km.

High-precision geodetic network (HPGN)



- points are at a distance 150 - 300 km;
- RMS of relative position is 1–2 cm;
- total number of HPGN points as of 1 January 2015 is 326.

Cartogram of planned HPGN points locations by 2020

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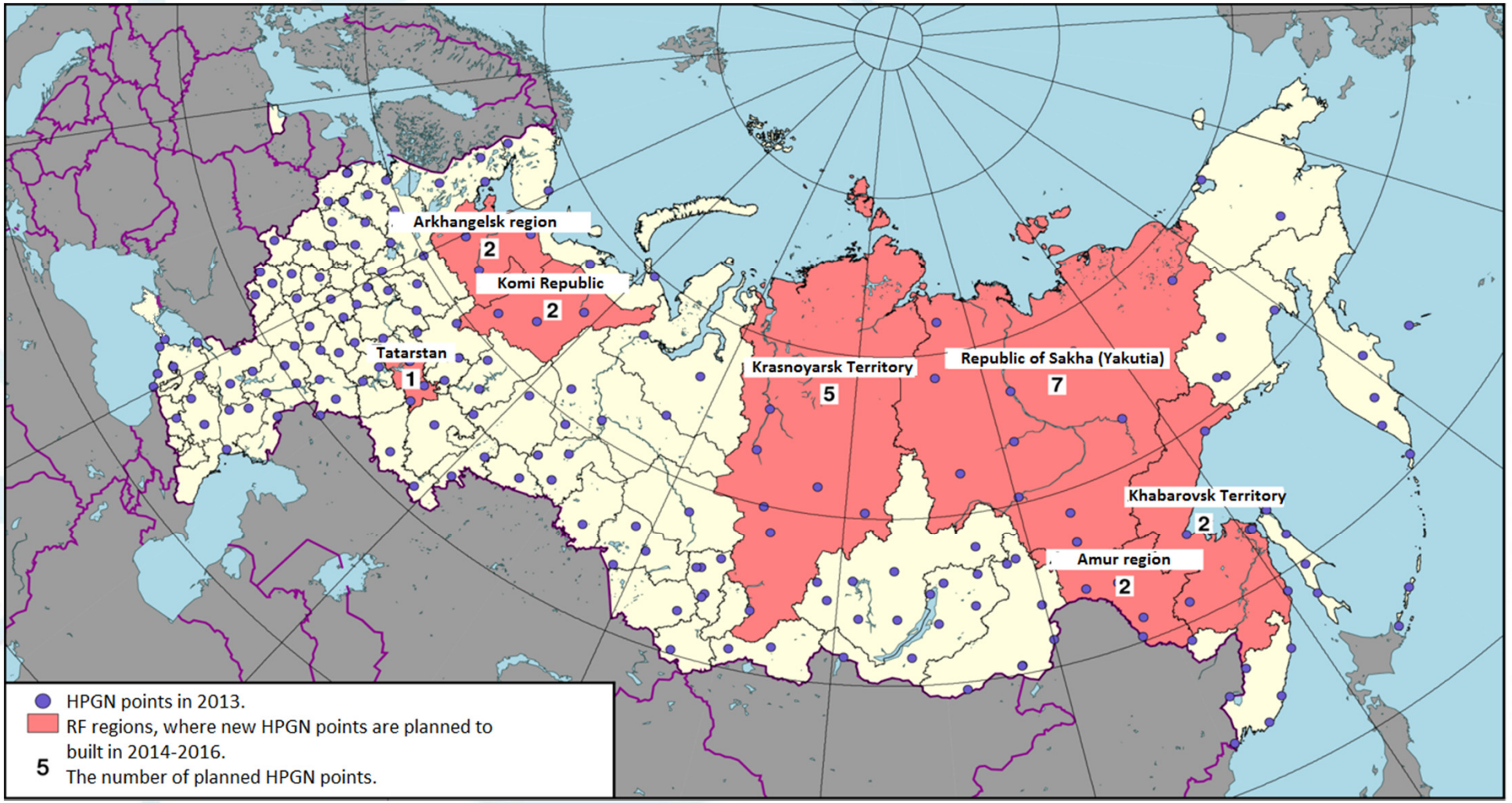
Planned target indicators of the network by 2020 :
number of points – 350;
positioning accuracy – 1-2 cm (horizontal), 1-3 cm (vertical);
relative position of the network points accuracy – 1-2 cm;
normative density – 20 points per 1 million square km.



Satellite geodetic network of the first class (SGN-1)

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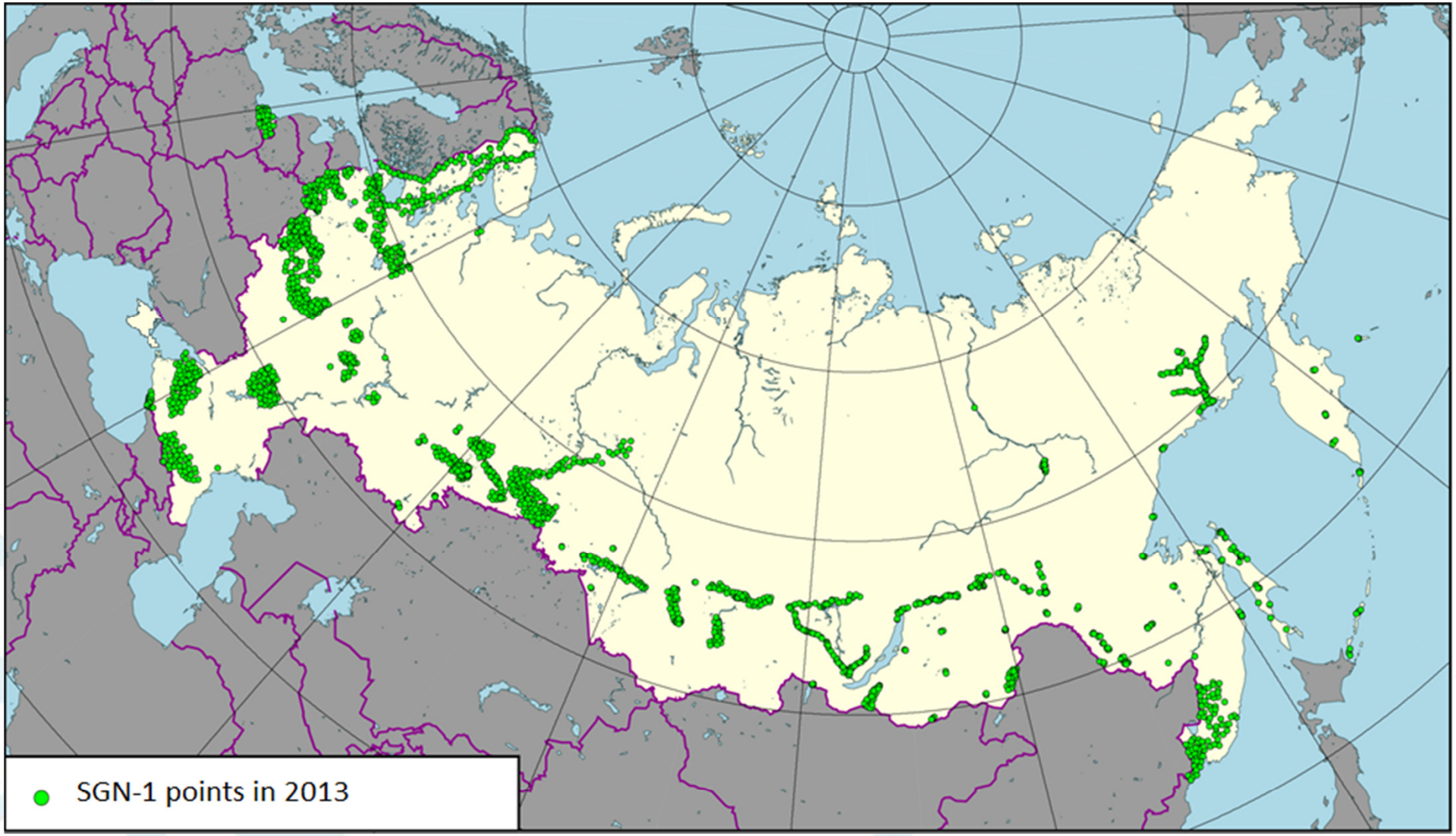

- points are at a distance 25 - 35 km with decreasing distance to populated areas and with increasing distance in uninhabited areas;
- RMS of relative position of SGN-1 points with reference to FAGN and HPGN points is 2–3 cm;
- total number of SGN-1 points as of 1 January 2015 is 4 244.

Cartogram of planned SGN-1 points locations by 2020

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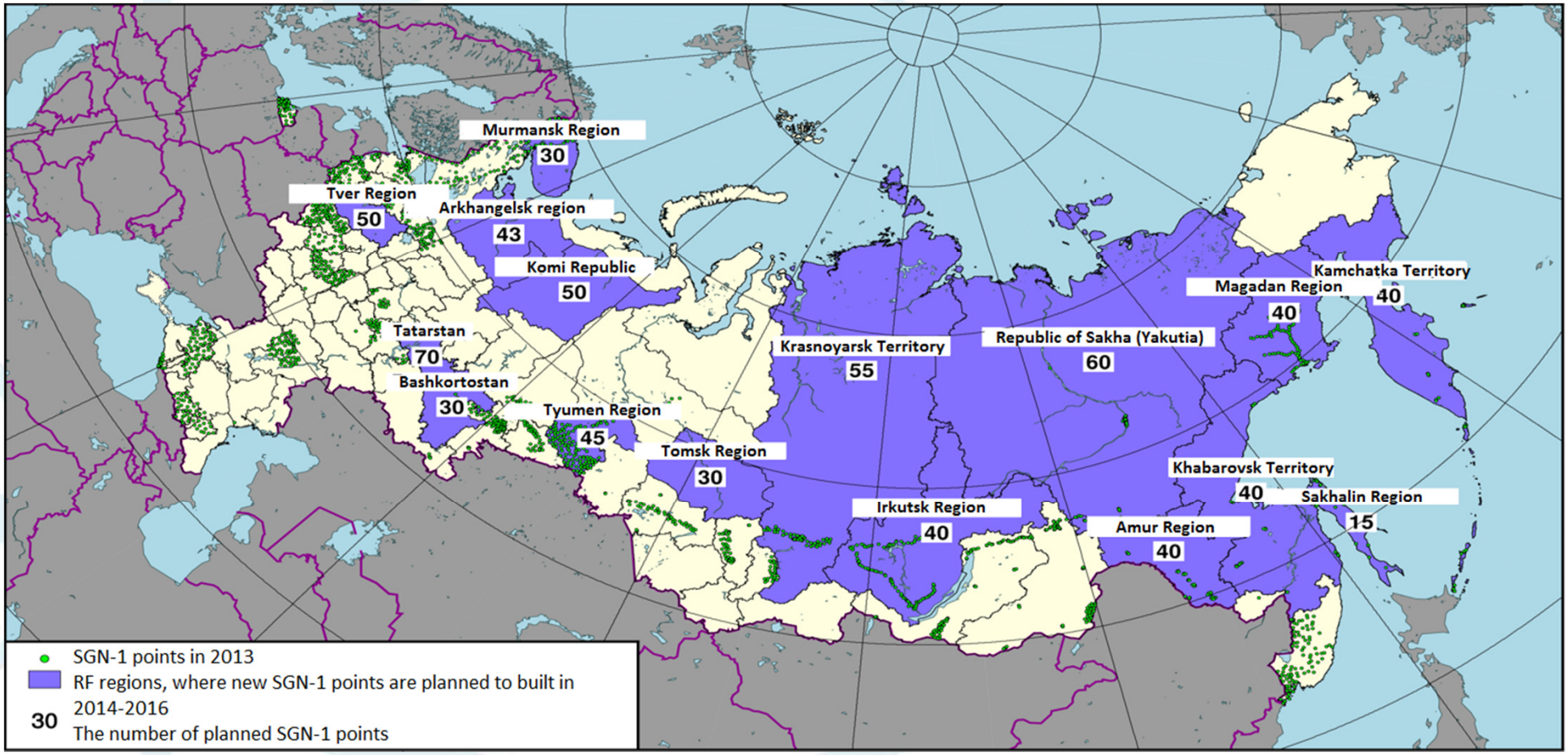
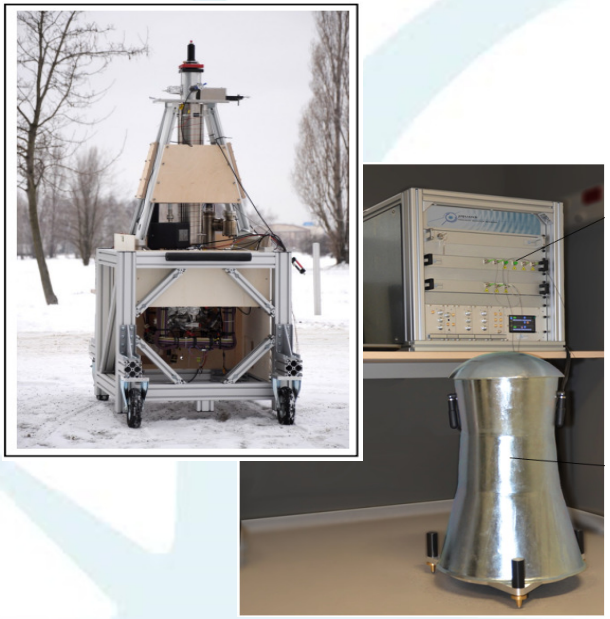
Planned target indicators of the network by 2020 :
number of points – 6000;
positioning accuracy – 1-3 cm (horizontal), 2-5 cm (vertical);
relative position of the network points accuracy – 1-3 cm;
normative density – 4 points per 10 000 square km.



IV. Perspective ground-based gravity tools for development of Russian geodetic support

Cold atom gravimeters

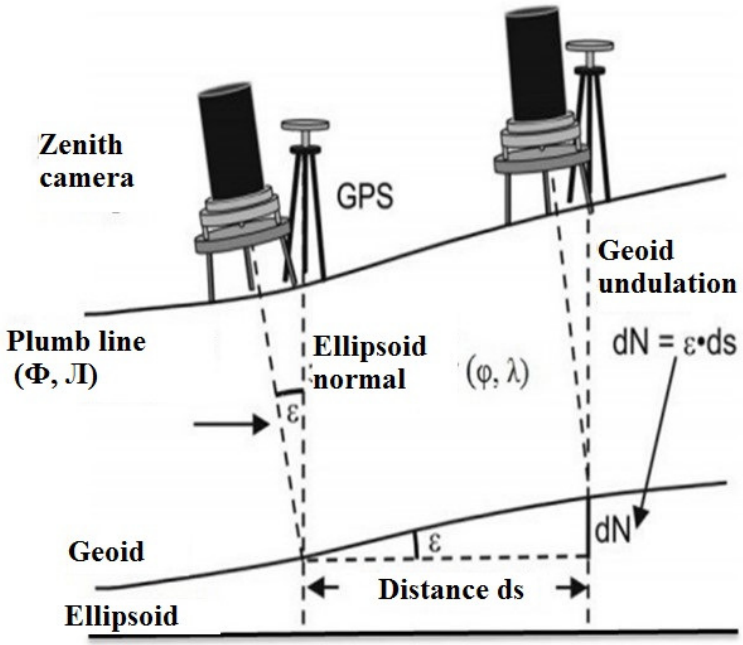


Gravimeter based on fountain time and frequency standard

$$\frac{\Delta g}{g} = (10-15)\cdot 10^{-9}$$

$$\Delta g_{\min} = 10^{-12}\ \mathrm{m/s^2}\ \left(10^{-3}\ microGal\right)$$

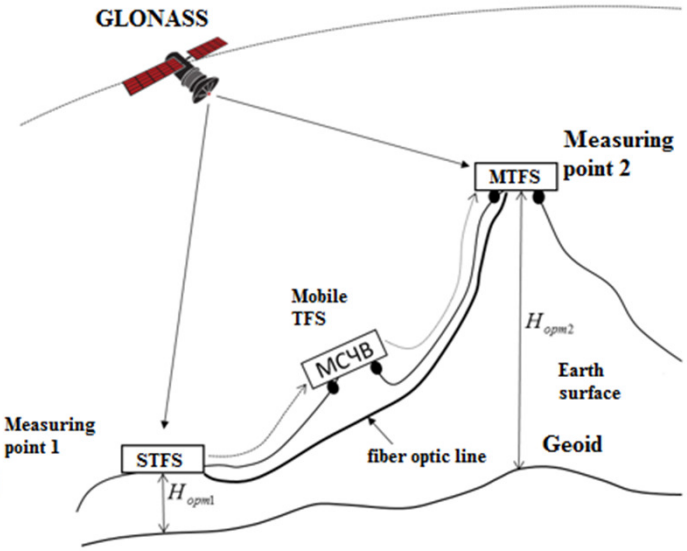
Digital astrogeodetic deviation of the plumb line gauge



Error:

$$\sigma_\gamma = 0.1'' - 0.05''$$

Difference of the gravitational potentials and orthometric heights gauge

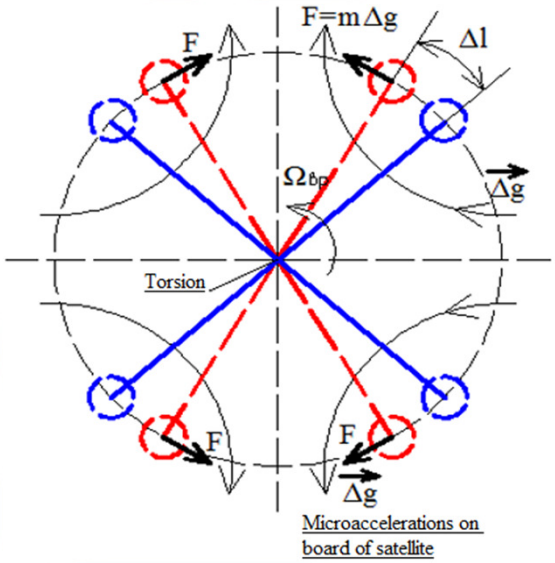


$$\frac{\Delta f}{f} = 10^{-17} : \ \sigma_H = 0.1\,m$$

$$\frac{\Delta f}{f} = 10^{-18} : \ \sigma_H = 1\,cm$$

IV. Perspective space gravity tools for development of Russian geodetic support

Rotational resonance gradiometers on the base of micro accelerometers



Experimental sensitivity

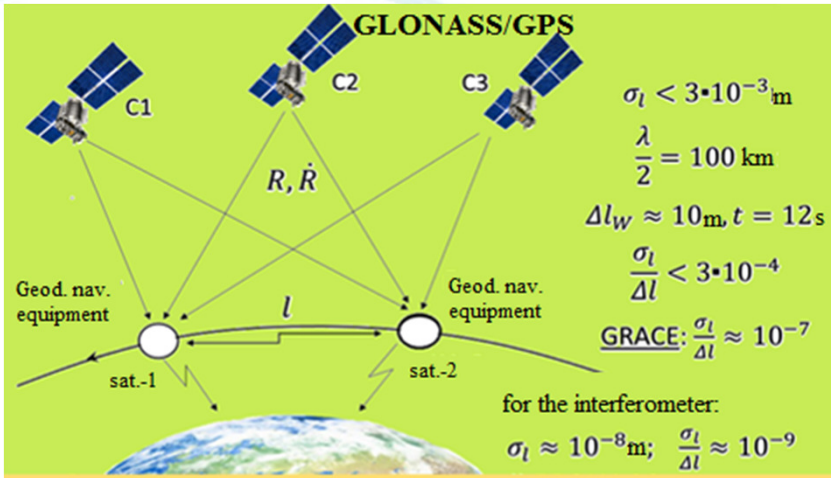
δW = 0,1E

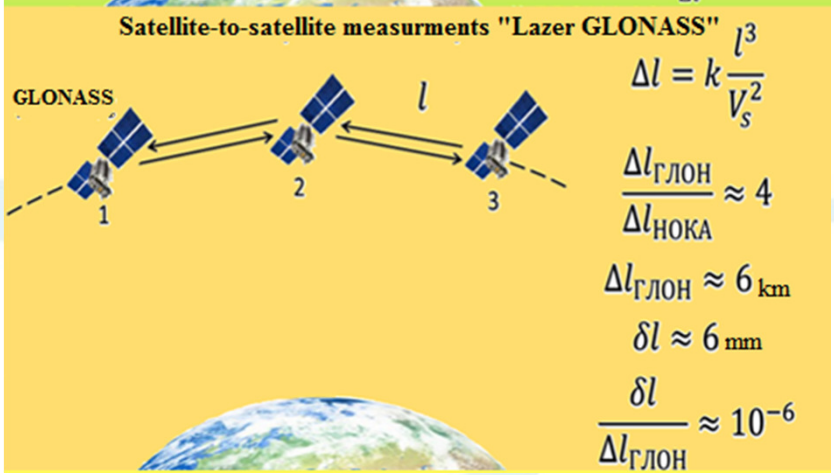
Ultimate sensitivity

δW = 0,001E.

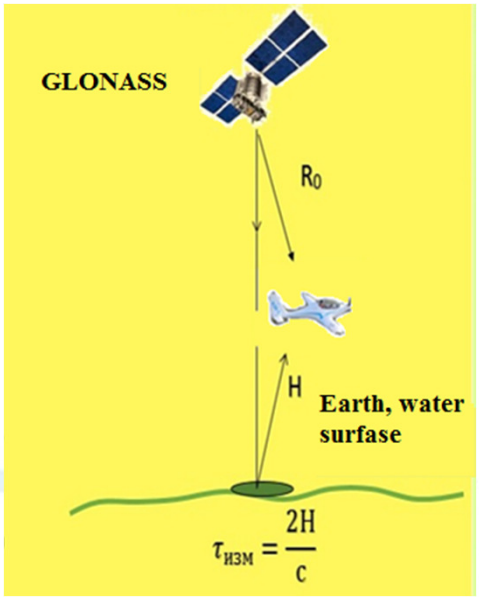
$$\frac{\delta_W}{W} = 10^{-6}$$

Satellite-to-satellite tracking





The radar altimeter measuring on the base of GLONASS signals reflected from the ocean surface



Parameters:

$$\sigma_H \le \frac{\lambda}{2}$$

Thank you!

i.gusev@glonass-iac.ru